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A REPORT

TO THE

PRESIDENT OF SEWER COMMISSION
AND DIRECTOR OF PUBLIC IMPROVEMENTS

ON

SEWERAGE AND SEWAGE DISPOSAL

FOR THE

CITY OF COLUMBUS, OHIO

MAY 6, 1901

RUDOLPH HERING
HYDRAULIC AND SANITARY ENGINEER.

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COLUMBUS, O., 1901
PRESS OF THE NEW FRANKLIN PRINTING COMPANY

Report of Rudolph Hering.

May 6, 1901.

Hon. Fred J. Immel, President Sewer Commission, and Director of Public Improvements, Columbus, Ohio:

Sir: In accordance with your request, outlined in a letter received from Mr. Julian Griggs, Engineer of the Sewer Commission, and dated February 2, 1901, to examine into the question of sewerage, drainage and sewage disposal with reference to the needs of your city, stating that:

"A review of all the work heretofore done is desired and the formulation of a report discussing fully the problem involved, including sewage disposal, recommending the construction deemed advisable or necessary, accompanied by estimates of cost and specifications, such as will command the respect and approval of the Ohio State Board of Health,"

and adding that

"all surveys, office work by draftsmen and computing which is deemed necessary can be furnished from the office of the City Engineer."

I respectfully report as follows:

March 11 to 14, inclusive, I spent in your city looking over the ground and the results of the studies which had heretofore been compiled, and which had a bearing upon the subject under consideration. The southern part of the city was especially examined, with a view to ascertaining all practicable sites for sewage treatment, for the location of a pumping station, main sewers, etc. A general examination was subsequently made of all existing data, reports and plans which referred to the subject.

Another visit to your city was made recently, during which certain provisional conclusions and results were verified, and on April 29, a preliminary oral report was presented to yourself and the Sewer Commission.

My thanks are due to your board for furnishing me with all necessary facilities for the present investigation, and also to Mr. Julian Griggs, your Chief Engineer, who placed at my disposal very full information concerning this work, in the shape of

preliminary studies, data and plans, and also a report which he had prepared on the question of sewerage, drainage and sewage disposal, including improvements and extensions, which he recommended for the interior sewage collecting system of your city.

In this investigation I was also personally and ably assisted by Mr. William B. Fuller, Civil Engineer, of New York.

PRELIMINARY.

GENERAL CONDITIONS.

The city has been provided with about 147 miles of sewers, of which 70 miles are of brick and 77 miles of pipe. They were designed and built as the demands for a sewer or drain presented themselves in any specific locality or street. Naturally, some haphazard and imperfectly conceived constructions now exist. Some sewers are useless, and many are either of insufficient capacity or possess other defects, thus rendering the problem of betterment somewhat intricate and difficult. No study of a comprehensive system had been made until within the last few years, and no practical results from such a study have as yet been realized on the ground.

The general topography of the city is not unfavorable to an effective and economical collection of the sewage; although it will be necessary to pump all of the sewage, before it is delivered to any point where it can receive treatment, and, on the west side of the river, much of the territory is so low that rain water falling upon it must also be pumped, in order to maintain this territory in the best habitable and sanitary condition.

In the upper or northern part of the city, the Olentangy river joins the Scioto river, which subsequently flows through the city and now receives into it at all times all of the collected sewage. When the flow of this river is large no objectionable results appear, but at other times, particularly when the river is low, much offense is caused by this entrance of sewage, which then sensibly, and sometimes greatly, pollutes the entire river.

PROBLEM STATED.

The problem which is now before you is, first, a co-ordination of the existing sewers, so that they conform to present local requirements and act together as a single harmonious system, both during rain storms and at ordinary times, and, secondly, a purifi-

cation of the sewage to the extent necessary to maintain the river at all times in an unobjectionable condition.

The first step taken towards intelligently solving this problem was a report to the Director of Public Improvements, made in 1898, by Julian Griggs, C. E., Chief Engineer, and John W. Alvord, Consulting Engineer, on the proper disposal of the sewage of the city and on a project for the sewerage and drainage of the territory west of the river. This report shows an able and thorough investigation of these subjects and reaches the following conclusions:

1. The separate system of sewage collection is recommended for the West Side, by which the sewage is kept apart from the storm water, brought to the river at Stimmel Road and there pumped into the river continuously.

2. An efficient storm water removal for the West Side requires that this water be pumped into the river during its high stages.

3. This pumping station, required for both sewage and storm water removal, is located on the east side of the river opposite Stimmel Road.

4. The sewage from the east side can flow into the river by gravity at its high stages.

5. The dry weather sewage now flowing into Alum creek is recommended to be pumped so as to flow into the present intercepting sewer.

6. The separate system is recommended in the suburban districts of the city wherever practicable.

7. For the purification of the entire sewage of the city, estimated at 20 million gallons per day, the use of artificial biological coke breeze filters was recommended, covering 36 acres of land, located near the proposed pumping station. The suggestion was then made that at first an experimental installation of about two acres be provided.

These recommendations have not yet been carried out. Since it was found that coke breeze filters cannot be relied upon permanently to purify the sewage at high rates, without periodical renewal of the material at a large expense, this part of the recommendations has been withdrawn. Meantime, progress was being made in England, which indicates that the so-called septic treatment of sewage, by which solid matter suspended in the sewage

is partially liquified, might reduce the expense of sewage purification. Both Mr. Griggs and Mr. Alvord, relying chiefly on recent European, but also on American reports, last autumn recommended the septic process for adoption because of the reported saving of cost.

The building of 20 concrete tanks was suggested by Mr. Griggs, each having a capacity of 500,000 gallons, and holding the sewage 12 hours, during which time a 50 per cent. purification was expected, measured by the reduction in albuminoid ammonia, and this effluent was to flow directly into the river at all stages. "Non-use of the river below Columbus for manufacturing or water supply purposes, the comparatively short distance within which a purification" of the raw sewage "is now effected by natural processes, and the absence of a large population living upon the banks of the river below the disposal works," seemed to them sufficient to warrant the adoption of that method.

Subsequently, Mr. Griggs discovered that some of his authorities had been misled, and that several of their statements needed correction. Yet, prior hereto, the suggestion to use septic tanks had been presented to the State Board of Health, which investigated the practicability of using them for the disposal of the Columbus sewage. A committee of the board visited a number of American cities where this disposal system was in use, and reached the conclusion that it might be liable sometimes to create a nuisance, that it was yet in an experimental stage, and that its adoption at this time without subsequent treatment would be unwise. The Board of Health approved the conclusion of its committee.

PRESENT INQUIRY.

A further search was then instituted by the city for an economical method of disposing of the sewage of Columbus, which would give unquestionable assurance that at no time a nuisance would be created in the river or elsewhere; and the present inquiry has been made with this end in view.

Inasmuch as the questions here to be considered refer both to the proper method of collecting and of disposing of the sewage; and, further, as the method of collection depends largely upon the manner by which the sewage is to be finally disposed, the inquiry will be divided into these two subjects, and the disposal question treated first.

As a preparation for this inquiry, however, it was necessary

to make some minor investigations. From an economical point of view it was essential to know the greatest amount of rainfall which the sewers should be expected to receive and carry off below the ground. This matter received careful attention.

Other economical questions required an inquiry into the general alignment of the main sewers, and into the relative advantages of a single combined or of a double separate system in any part of the city.

Then it was necessary to consider the flow of the Scioto river at different months and seasons, so as to know its capacity for receiving sewage at different times to an extent that would at no time render a nuisance.

Borings made on the most suitable lands for sewage treatment gave discouragement to the belief that any inexpensive, and at the same time satisfactory method of natural sand filtration would be available. The best land indicates a preponderance of clay and loam, and only at a few places some sandy and light soil. A pretty thorough examination of this land appears to have been made for the report of Mr. Griggs and Mr. Alvord, above mentioned, but the recent examinations have caused me to form the opinion that, with a conservative view, we could hardly expect results as good as those that were previously estimated.

Sand of excellent quality for the purpose of sewage purification can be procured from distant localities at a price which makes its use feasible for the present purpose. Several kinds of such sands were examined and prices were obtained for a delivery in large quantities. Mechanical analyses, the results of which are shown in an appended table, indicate several sources from which sand of satisfactory quality could be procured.

Finally, estimates of cost for the different treatments have been prepared, and careful consideration was given to the best ways in which the most economical solution of the disposal question could be reached with assured satisfactory results at all seasons.

DISPOSAL OF SEWAGE.

The report of Messrs. Griggs and Alvord enters so fully into the aspects of the general question regarding the quantity and quality of sewage requiring consideration in this case, the principles which should govern the disposal of the sewage, the description of the various methods employed for the same and the

experience of other cities, that it is necessary to refer here but briefly to them, adding, perhaps, some slight modifications.

QUANTITY.

The quantity of sewage is usually measured by the water supply, but is occasionally augmented by ground water seepage and reduced by evaporated water, particularly in summer, when considerable quantities are used for sprinkling.

In sewers to which rainwater is admitted, the quantity of flow varies more with the intensity of storms than with the amount of domestic water supply. Concerning the disposal question ,it should therefore be said that the mixture of rainwater with sewage, increasing the quantity of water to be dealt with, can be allowed only where overflows into large water courses are practicable. In the case before us, we have a large river into which such overflows and sometimes even all of the sewage can discharge, as will be seen later. Therefore, in providing for a purification of the sewage when necessary, we need consider only the quantity of dry weather flow, which for the present purpose can be assumed to equal the water supply and seepage.

As the entire population of the city is not yet provided with sewerage facilities, although it may be supplied with water, the total quantity of sewage to be purified should be less than the total quantity of this water. Mr. Samuel M. Gray, in his recent report, on the water supply of your city, recommends for the present population a supply averaging 16 million gallons daily. It appears to me that if for sewage purification purposes we now take into consideration a daily flow of 20 million gallons, we are making an ample provision for any works, the nature of which will allow ready extension at any time. This quantity of sewage was suggested also by Messrs. Griggs and Alvord.

QUALITY.

The Columbus sewage is not strong. Both the water consumption per capita and the analysis of the sewage indicate this conclusion.

The sewage has a decided alkalinity, and is therefore amenable to the best methods of treatment. An analysis was made by Professor N. W. Lord, of the Ohio State University, of the sewage from the interceptor during ten days in February and March, 1897. The following table gives its averages, and also

gives the composition of the sewage of Lawrence, Mass., for 1896, in parts per 100,000:

	Free Ammonia.	Albumiroid Ammonia.	Chlorine.
Columbus	0.508	0.378	3.10
Lawrence	4.330	0.790	9.86

The comparison indicates that the Lawrence sewage is more than twice as strong as the Columbus sewage. As the Lawrence experiments (Report for 1899, p. 461), have shown that the rate of purification in filters depends on the amount of unoxidized matter present in the sewage, and that a sewage twice as dilute as another is equally well purified at a double rate of filtration, other conditions being equal, we have a means of applying the Lawrence results to our own case.

The character of sewage changes with its age and its opportunities to undergo bacterial action. Fresh sewage contains free atmospheric oxygen, derived from the water supply, and under bacterial influences its carbonaceous matter is oxidized until the dissolved oxygen is exhausted. This initial step in the decomposition of sewage is inoffensive and produces a product which is called stale sewage.

Finally, as bearing on the question of quality, we must consider that some of the matter in sewage is dissolved and some is suspended. The latter forms the troublesome element. The chief purpose of all preparation for a final purification of sewage is the prior removal of as much of the suspended matter as practicable, because that which is dissolved can be oxidized with much less difficulty.

GENERAL METHODS.

The methods available for a disposal of sewage may be grouped into three classes. The first renders it inoffensive by ample dilution in flowing water. The second purifies it by allowing it to percolate through porous soil. The third reduces its suspended matter as well as dissolved organic matter, either by sedimentation or by liquefaction due to bacterial processes, both being a preparation for a more effective treatment either by dilution or by filtration through soil.

DILUTION.

It is common knowledge that sewage discharged into a water course will, if the latter is large enough, disappear to sight and smell. It is the most inoffensive and inexpensive of all methods

of disposal, and is practiced wherever possible. The bacteria and the oxygen dissolved in the water act as the chief purifying factors. As this oxidation is slow, the dilution process as applied in practice is based on the mere endeavor to render the sewage inoffensive, but not immediately to purify it.

We have had quite an experience with the effects of discharging city sewage into flowing streams, and it has been found that up to certain limits such a discharge is sure to cause offense, and beyond them it is equally sure to cause no offense.

Recorded experience on this question leads to the conclusion, with reference to Columbus conditions, that the Scioto river at certain times can receive a large amount of sewage without causing offense. The limiting amount, fixed after a careful inquiry and comparison with other cases, can be obtained by the formula, that, after a prior sedimentation, the sewage from 1,000 persons may be safely diluted by a river flow of four cubic feet per second, and is rendered inoffensive thereby.

It was necessary, in order to know the diluting capacity of the Scioto river at various periods, to ascertain its monthly flow. Unfortunately, exact data giving this information are available only for the short time since January, 1899, when a series of observations was started by the Ohio State University, at the request of the State Board of Health.

Although these last two years were very dry, and therefore well adapted to assist in the present purpose, it was desirable to supplement their evidence by further information. It was found possible to do this by utilizing the results published in a report on "Survey of the Miami and Erie Canal," by Captain H. M. Chittenden.* In this report monthly gaugings were made of the run-off of the Muskingum river at Zanesville, from December, 1887, to November, 1895, inclusive. The topographical conditions are not very different from those of the Scioto river watershed, although it is probable that the summer rate of flow of the latter is somewhat less than that of the former.

Table "A," in the appendix, shows the estimated and observed monthly run-off of the Scioto river in inches of rainfall, based on all the available information. For the three years, 1896, 1897 and 1898, during which there were no observations, only an estimate could be made, basing it on proportions similar to those found in the other years.

From this information Table "B," was prepared, also found in the appendix, giving the population whose sewage could have

* Abstracted in the appendix.

been diluted, from 1888 to the present time, by the flow of the Scioto river at Columbus, on the basis that the sewage of 1000 persons could be satisfactorily diluted by a river flow of four cubic feet per second, and that the population whose sewage had thus gone into the river had constantly been 125,000. The table shows that upon this basis there would have been no offense during all those months, printed in full faced type. Where italics appear, there would have been an insufficient river flow for diluting all of the sewage , and consequently a more or less undesirable pollution of the river. It shows that during the dry years, 1899 and 1900, for seven and eight consecutive months, the river flow was not large enough to give a proper dilution. On the other hand, with the rainfall which occurred in the year 1888, there would have been but a single month during that year when the flow was insufficient; with the rainfall of the following year, there would have been an insufficient dilution for four months, and with the rainfall of the year 1890 the river could have properly diluted all of the city's sewage throughout the entire year.

If the proposed storage reservoir for the water supply is built at Lakin Place, the flow of the river below will be lessened during the summer months; but it would be correspondingly increased during the other months when water power was being used from the stored supply.

It is very clear from these tables that in wet years and during the wet months of other years, the Columbus sewage can be satisfactorily disposed of by dilution, as done in most of our other large cities. It is also clear that in dry years and for a number of consecutive months, nearly all, and sometimes the entire quantity of sewage would have to be excluded from the river. Another disposition for it must, therefore, be made, and some method of purifying the Columbus sewage consequently becomes imperative.

There are two methods by which adequate purification may be accomplished:

BROAD IRRIGATION.

The practice of irrigating with sewage is quite old, and has been more or less successful, according to the climate, the character of the soil, the sewage and the plants cultivated upon the land.

South of Columbus a fairly suitable tract is available for ap-

plying this method. It presents some advantages in being level, and, although mostly clay soil, it contains some soil which is fairly light and porous. After examining this soil I am of the opinion, however, that it would not be safe to risk the permanent daily application of more than 10,000 gallons per acre even during periods between heavy rains, before causing it to become overloaded. For the present population this would mean perhaps 2000acres of such land. It also seems to me that it would be a questionable undertaking successfully to raise crops upon this land, because there are occasional occurrences when the necessity for putting sewage on it would not correspond with the need for more water on behalf of the crops, and if put on in spite of this fact, might cause them an injury. Such conditions would arise in summer, when the river is low and cannot dilute any sewage, and when a shower or sudden and sharp rainfall increases the flow of sewage from the city, but not materially the flow of the river. The land, already saturated, would have to be further deluged by the sewage discharged upon it at the time.

Another disadvantage of the broad irrigation system in your case is the necessity for the city either to operate a sewage distribution plant irrespective of crop raising over a very large territory, or to lease the land for this purpose of crop raising and thereby to create divided and sometimes opposing interests. Permanently satisfactory results could not be expected in either case.

INTERMITTENT FILTRATION.

By abandoning the idea of utilizing sewage for agricultural purposes, and concentrating the water with the single purpose of securing its purification, we use the so-called intermittent system of filtration, by which the sewage is run over a given area of land, allowed to soak into the ground, the application being repeated after a certain period of rest.

Of all methods this one has given the greatest satisfaction in the way of sewage purification, and has been and is successfully used both in Europe and in America. The details of the operation are so well known that with a given quality of sand and known diameter of its grains, and with a proper construction of the filter beds, it is possible to foretell within certain narrow limits how much sewage of a given composition can be purified thereon, and what degree of purification will result during summer and winter seasons.

The application of this method in your case requires an artificial construction of all the filter beds. No natural sand areas of the proper kind are available near your city. As already mentioned, sands from other localities were examined, and their effectiveness determined. The result has been to show that with such artificial beds and their use during the months when the Scioto river cannot satisfactorily dilute the sewage, the purification can be accomplished at rates running up as high as, and probably higher than, 250,000 gallons per acre per day.

Table "C," of the appendix has been compiled to show, for conditions like those existing from 1888 up to the present time, the different rates of filtration per acre per day which would have been necessary to dispose of the sewage of 125,000 persons on 80 acres of filtration beds, after deducting the proportionate amount of sewage that could have been safely discharged into the Scioto river.

From this table it is seen that had the sewage from 125,000 persons required an inoffensive disposal in 1888, such filter beds would have been operated for one month at the rate of 44,000 gallons per acre per day; in 1889 for four months at an average of 113,000 gallons per acre per day, and in 1890, the beds would have rested the entire year. Then, in 1891, they would have been worked for three months at an average of 66,000 gallons per acre per day, etc. The greatest work would have been done by the beds in the year 1900, when they would have been employed for eight months at an average rate of 143,000 gallons per acre per day.

In order to obtain rates as high and higher than those contained in the table, and for the purpose of economizing in the total area of artificial sand beds, it is desirable to prepare the sewage for this high rate of filtration by removing from it as much of the suspended matter as may be found practicable; and also where feasible to render the organic matter of more favorable composition. It is chiefly this suspended matter, as already stated, that reduces the rate of filtration, and therefore increases the necessary area.

REDUCTION IN SUSPENDED MATTER.

Suspended matter can be removed from the sewage by reducing the flow to that of comparative rest, when, either by gravity alone or by assisted precipitation, this matter will settle and deposit. Or, it can be removed in part by allowing a natural lique-

faction of the organic matter to take place. The former method is accomplished either by chemical precipitation, by settling or subsiding basins, and the latter is accomplished by the use of bacterial processes, which incidentally also improve the condition of the organic matter for subsequent filtration.

PREPARATORY TREATMENT.

By their reduction of the suspended matters, these processes cause clarification, and in a measure they correspond to the preliminary treatment of very turbid river waters prior to filtration of water supplies. When applied to sewage they differ, of course, due to the fact that in sewage there is a far greater amount of organic matter, as compared with mineral matter, than in turbid river waters.

All of these mentioned preparatory treatments of crude sewage effect an appreciable reduction in organic matter, and may properly be called processes of partial purification. But they never effect complete purification in the sense of the term as used in current practice, although it is true that in some cases a partial purification suffices to prevent nuisances. Strictly, they should all be classed as preparatory treatments, and may be divided into the following procedures: Settling, septic action, chemical precipitation and filtration through coarse grained material.

So many descriptions of these processes have been recently published, that it will here suffice to give a brief synopsis of their leading characteristics from a practical standpoint, and with reference to their applicability to the local problem.

SETTLING OR DETRITUS TANKS.

Fairly fresh municipal sewage always contains a certain portion of its suspended matter in such a condition that it can be readily removed by subsidence. This portion of the suspended matter consists of mineral substances, made up in a large measure of street washings, etc., and subsides quickly. In a settling tank holding about two hours' flow of sewage, corresponding to an enlarged so-called grit chamber, it is feasible to remove the comparatively coarse particles in suspension. Combining with this first step efficient screening, a material improvement is obtained in the quality of the sewage, as it lessens clogging at the surface of the filters. The proportion of mineral to organic matter in the deposited sludge is relatively large, and the sludge from

time to time can be removed from the settling tanks at a moderate cost, and disposed of without producing a nuisance.

After this settling, the ordinary municipal sewage retains in suspension matters which are largely organic in their composition and relatively small in size. The latter feature affects their hydraulic subsiding power, and tends to lessen the efficiency of the plain subsiding process. A complication also arises from decomposition processes taking place in the suspended particles, which, resulting from bacterial action, are gradually disintegrated. Furthermore, the consequent formation of gas bubbles attaching to these particles tends to their upward movement. Therefore, the putrefaction of suspended organic matter not only retards and diminishes the effect of plain subsidence of sewage, but also produces conditions associated with nuisances in disposing of foul and rapidly decomposing sludge.

Practical experience has demonstrated in the case of strong municipal sewages that there is very little merit in plain subsidence as a preparatory treatment following the deposition of coarse mineral matters. In the case of a sewage as dilute as that of Columbus, there are reasons for believing that plain subsidence may have considerably more practical merit. These reasons are associated with the relatively small amount of organic matter which it contains.

SEPTIC TANKS.

Within the past five years much has been written concerning the process which is generally known as the septic tank treatment. In brief terms, it combines the results of subsidence and of bacterial processes, arranged with the view to bring about the detention of the suspended matters in the tank and their subsequent liquefaction by the bacteria. From a theoretical standpoint, and upon a small scale in practice, this process has been worked out in a number of cases with much care, and the available evidence promises results of considerable practicable merit. But it is not yet practicable to forecast the thoroughness of the preparatory treatment which this process affords to a given sewage, owing to the lack of information regarding the precise influence which the character of the particular sewage has, either in facilitating or retarding the processes upon which this treatment depends. When properly applied it effects a substantial clarification of the raw sewage, and especially brings about a liquefaction of a portion of the deposited sludge to an extent that it materially

reduces the trouble and expense of removing and disposing of the latter.

In view of the fact that a considerable portion of the suspended matters in sewage is of a mineral nature, it is obvious that the septic process is incapable of effecting the liquefaction of the entire amount of sludge, as sometimes believed. Accordingly, the septic action ought not to be immediately applied to raw sewage, but follow plain subsidence in a separate settling tank, from which it is quite practicable to remove from time to time the grosser suspended matters of a mineral nature.

With Columbus sewage the indications are promising that a combined detritus and septic tank treatment could be arranged to effect a substantial improvement in the character of the raw sewage, at moderate cost for both installation and operation, and without producing a nuisance. In fact, the diluteness of the Columbus sewage would probably allow the septic tanks themselves, independently of the detritus tanks, to be operated for a year or two without the necessity for removing the accumulated mineral matter from the bottom.

The differences in arrangement of plant between the two processes are relatively small. In the septic tank suspended matter accumulates not only on the bottom, but also at and near the top or surface, due to what is brought up by bubbles of gas. Between the two is a liquid comparatively free from suspended matters, and showing the results both of subsidence and bacterial action.

With regard to the size and arrangement of combined settling and septic tanks for the treatment of the Columbus sewage, some uncertainty exists because it is not known how long this sewage should undergo septic action in order to effect the best results. This period, subsequent to the sewage leaving the detritus tanks, may apparently be about 12 hours. In England, where the sewage is much stronger, a period of 24 hours has been found to give the best results. Detailed local studies may show that in Columbus this period can properly be reduced to less than 12 hours. At the outset, however, it seems advisable to construct the basins on a 12-hour basis. Should they be found larger than is absolutely necessary, the reserve capacity can be used for the increased flow of sewage.

Concerning the degree of improvement of the sewage to be expected from the treatment by both detritus and septic tanks, the

evidence indicates that there could be expected a reduction of suspended matter approaching 60 per cent., and of organic matter over 25 per cent. of that contained in the raw sewage.

As wind storms may disrupt the surface layer or scum of suspended matters entrained by the gas bubbles, which form at times a fairly efficient cover to septic tanks, it is wise to roof them. A roof also guards against the dissemination of odors, and maintains the temperature of the sewage.

CHEMICAL PRECIPITATION.

One of the best known processes for the elimination of suspended matters, is that known as chemical precipitation. It consists of the addition of a suitable chemical, which, upon its decomposition by or combination with the constituents contained in the sewage, forms compounds which envelop the suspended particles and facilitate their deposition as sludge. To effect this deposition it is customary to provide subsiding tanks holding from 40 per cent. to 50 per cent. of the daily dry weather flow of sewage. A comparatively voluminous sludge, containing some 97 to 99 per cent. of water, accumulates at the bottom, and from time to time must be removed to avoid nuisances from putrefaction.

This process effects the removal, according to the composition of the raw sewage, of from 80 to 95 per cent. of the suspended matters and of approximately 50 per cent. of the total organic matter originally in the raw sewage.

As an independent treatment of sewage, it therefore only half solves the problem, and this at considerable expense. As a clarifying process preceding filtration it is very efficient, and notwithstanding its expense it is retained as a part of some of the larger remodeled purification plants in England. For the Columbus problem it does not offer the economical advantages which can be obtained by detritus and septic tanks.

FILTRATION THROUGH COARSE-GRAINED MATERIAL.

For the past ten years much study has been given to the behavior of beds constructed of coarse material, properly called coarse-grained filters, to distinguish them from sand filters. They are of artificial construction; built either of gravel, broken stone, coke, cinders, or some such material. Their relation to sewage purification has been studied with reference to several different methods of operation, the most prominent of which are as follows:

A. Roughing filters, usually operated intermittently, and serving not only as effective means of straining and clarification, but also in the reduction of the dissolved organic matter through bacterial processes.

B. Contact beds, operated by filling the pores of the beds with sewage, allowing it to stand several hours and then slowly to drain out from the bed. Normally ,they are so operated that three complete cycles of the several steps of the process may be completed in 24 hours.

C. Continuous filters, in which the sewage is continuously discharged upon beds in the form of a fine spray from a series of stationary or moving jets.

As a rule these coarse-grained filters are constructed of much greater thickness than intermittent sand filters. Some recent projects in England provide for a thickness of from 8 to 10 feet. All such artificial filters are expensive in their installation, and, so far as appears at present, they are also very expensive in operation and maintenance, when raw sewage is applied to them, because they soon become clogged and require rejuvenation at a cost approximating that of their first installation.

In England the sphere of usefulness of this type of filter has been found in the treatment of a well clarified effluent, coming either from chemical precipitation or septic tanks. Generally, the rates of filtration are high, ranging from about 1 to 2.5 million gallons per acre daily, according to the strength of the applied liquid. The effluents are quite turbid and uninviting in their appearance, but contain as a rule no more unstable organic matter than can be provided for by the oxygen which they contain.

Rating these coarse-grained filters according to evidence about which there is no question or dispute, it may be said that their field of usefulness seems to be associated with the treatment of very strong sewages.

These processes seem quite attractive when the filters are first placed in operation; but their permanency appears questionable, particularly as to the period of service which can be expected at the regular high rates, without large expenses for repairs and rejuvenation.

Until the evidence becomes more decisive in their favor, it is not judicious to adopt them in large projects, wherever intermittent sand filters can be built at a reasonable cost, and concerning

which there is no uncertainty whatever, either with regard to efficiency, permanency or cost.

RESUME AND CONCLUSIONS.

The existence of the Scioto river, with its relatively large watershed and the fact that no public supply of water is taken from it for domestic purposes for a very long distance below the city, justify the conclusion that the city's sewage, after it has been freed from coarse suspended matter, can be discharged into the river in such quantities as we know will, by proper dilution cause no offense.

As the river rises and falls, and changes in the quantity of its flow, so should the discharge of sewage into it be varied and regulated to preserve a safe degree of dilution at all times. This safe degree can be obtained by a flow of at least four cubic feet of river water per second for the sewage of 1000 persons, after it has passed through tanks providing subsidence and septic action.

When the river flow is not sufficient thus to dilute all or any part of the sewage, then, whatever is the quantity of sewage which cannot be diluted, it must be purified before its discharge into the river.

The method of purification recommended to you for this purpose is that obtained by intermittent filtration through beds of sand, located on the tract which was suggested for this purpose a few years ago, namely, on the Miller and Schwenker farms.

There being an insufficient amount of sand for this desired purification on the ground itself, it is necessary to bring to it the necessary quantity of sand of proper quality, and to construct artificially the entire filter beds.

In order to make their filtering capacity per acre as efficient as possible, in other words, to obtain as high a rate of filtration as consistent with the desired degree of purification, a preparatory treatment of the sewage becomes necessary.

Taking all of the available evidence into consideration, with reference to this problem, it is recommended to you, first, to employ a series of tanks, in the first of which the coarser suspended matter of the sewage would be deposited and from which it can be easily removed, and then, in the remaining and greater proportion of which a septic process would further eliminate the deposited suspended organic matter by its liquefaction.

It is not practicable in the absence of specific knowledge of the Columbus sewage and of its peculiarities, to indicate at this

time specifically all of the elements and details which are necessary to accomplish its purification in the most economical manner, and to state the exact area of filters to dispose of that part of the sewage which cannot be discharged into the river.

It is, therefore, recommended that the tanks for preparatory treatment and the filter beds be built in such a manner that from the best present general and local knowledge the desired results will be reached, but to install only a part of the filter plant, say 10 acres thereof, at the present time, and to operate the same for at least one year, for the purpose of ascertaining, under skillful supervision, its greatest possible efficiency and economy. The construction of the remaining part of the plant can then be continued, after knowing with definiteness its best proportions and its best mode of arrangement and operation. In this way advantage could be taken of improvements made elsewhere in this field.

The variation in the character of the sewage, according to the hour, day and season, should then be ascertained in connection with the best operation of the different parts of the plant, the most effective periods of rest, both in the tanks and on the filter beds, the greatest safe rate of percolation through the latter, and the least practicable depth of sand that will secure the desired purification.

It seems probable that the cost of the recommended method, along present known lines, may then be materially reduced, without a sacrifice of efficiency.

It should not be understood that this suggestion of beginning with a part of the plant implies the construction of tanks or filters which may later be abandoned or essentially modified. The great expense of this work does not warrant the construction of a plant which has purely an experimental character. The proper and safe manner in which to proceed in this case is, in my opinion, to start with what we positively know will produce the desired result, and while operating the first part of the plant, observe by careful investigation all the specific phenomena occurring under the local conditions. The most efficient and economical details will thus become apparent, and the units of the large plant subsequently built can be added and constructed according to this experience. This method of procedure, rational and systematic as it is, appears to be the only one that will, without failure, secure permanently satisfactory works, and by progressing along har-

monious lines avoid patchwork or experiments of doubtful value.

Skillful and trained supervision for operating works of this nature is essential to their success. They need special intelligence to adjust variable conditions to constant ends, in the spheres not only of practical engineering, but also of chemistry and bacteriology.

COST.

From the best evidence available after careful inquiry, the following estimate of cost of a sewage disposal plant has been made. It is assumed that there should be a series of settling and septic tanks, sufficient at once to deal with 20 million gallons of sewage daily. It is further assumed that 80 acres of filter beds will be required, unless by subsequent investigation this area can be reduced. The estimate also includes all the appurtenances that would be required. Further details of cost will be found in the appendix.

Settling and septic tanks for 20 million gallon plant @ $7,575.00 per million gallons	$151,500 00
80 acres filter beds @ $8,940.00 per acre	715,200 00
Force mains and right of way from pumping station	84,961 00
Water mains and hydrants	8,723 00
Electric motors and pumps	3,000 00
Electric transmission and lamps	6,722 00
Well and pump house	2,500 00
Laboratory building	3,000 00
Laboratory supplies	1,000 00
Railroad siding and bridge	60,000 00
Total	$1,036,606 00
10 per cent. engineering and contingencies	103,660 00
	$1,140,266 00
Land	78,750 00
Grand total	$1,219,016 00

It is recommended, however, not to install the entire filter plant at first, but only 10 acres thereof for the purpose of closer study. Leaving all the other items as they were, except a reduction in the filter bed area, the immediate investment for this purpose would be:

Settling and septic tanks	$151,500 00
10 acres of filter beds	135,700 00
Other items as before	169,906 00
	$457,106 00
10 per cent for engineering and contingencies	45,710 00
	$502,816 00
Land	78,750 00
Grand total	$581,566 00

COLLECTION OF SEWAGE AND STORM WATER.

After having determined the best method of sewage disposal and the location of the disposal works, it is then possible to ascertain the merits of the existing and proposed sewerage system which you have proposed for collecting and bringing the sewage to the works.

As the sewage and some of the storm water require pumping, the best location for a main pumping station was examined, with the result that I see no reason to deviate from the general plan suggested by Messrs. Griggs and Alvord, as indicated and explained in their report.

It was necessary to examine also into the merits of placing a pumping station at Kelton avenue, and pumping the sewage from the Alum creek watershed into the main intercepting sewer running substantially parallel with the Scioto river, as against building a special intercepting sewer from the Alum creek territory to the main interceptor near the main pumping station.

Mr. Griggs made surveys and special investigations for this purpose, comparing the two problems, the result of which has been that it was found to be more economical at present to build the pumping station and not the intercepting sewer, which was to take its place. The latter, however, should be adopted as a future part of the system, to be built as soon as the territory through which it runs becomes more developed and makes the building of such a sewer, with its branches, economical.

I have examined the recommendations that have been made for the improvement of the West Side sewerage, and also see no reason for deviating from them.

Messrs. Griggs and Alvord recommended the introduction of the separate system, which, on grounds of economy and a better working of sewers on that low territory, I can fully approve.

The same treatment can also be recommended for some of the suburbs on the East Side, because it is often desirable to remove the sewage at once, while the underground removal of storm water can be postponed. Such extensions are, therefore, along the line of economy.

There is no advantage in having the separate system on the ground of the necessity for pumping sewage to the disposal fields, because the river can receive at times without objection a mixture of the two waters escaping from overflows.

The plans that have been prepared for the main pumping station should, in my opinion, be re-arranged on a somewhat more elaborate basis, by providing more room for the machinery and for its duplication. Otherwise the arrangements appear to me to be satisfactory. It would be well to interpose a large grit chamber, so as to retain and specially remove the heavier matter as it is brought down the sewers, before it reaches the pumps.

The main pumping station must be installed so that the storm water on the low ground of the West Side and the sewage from the whole city may be pumped. Messrs. Griggs and Alvord suggest pumps of 40 million capacity to do this work, and this seems to me sufficient for the first installation.

Mr. Griggs has estimated the installation of pumping machinery capable of removing one inch in depth of storm water per 24 hours over 1350 acres of land on the West Side, and at the same time the sewage of 18,000 people from the same side of the river. Together this amounts to about 40 million gallons per day, and requires about 200 net horse power. In dry weather this same machinery could be used for pumping to the disposal area the entire sewage flow, amounting to a maximum of 20 million gallons per day and requiring about 171 net horse power.

In dry weather it is proposed to intercept all the sewage on the East Side and take it to the main pumping station by the present interceptor. On the West Side it is proposed to build a portion of a new interceptor, leading the sewage to the pumping station, from which, together with the sewage of the East Side, it will be pumped to the disposal beds.

In times of rainfall and when the river rises, the sewage of the East Side can be run into the river by gravity, so far as this is permissible within the established safe degree of dilution. At such times the sewage, together with a certain proportion of the storm water of the West Side must be pumped for discharge into the river.

The general arrangements at the Kelton avenue station are approved with the understanding that in the future, the station will be abandoned for an intercepting sewer through the Kian Run district. A smaller station is suggested for collecting the sewage of a still lower area near Alum creek, from a territory which cannot otherwise be intercepted.

The alignment of the sewerage system has been gone over with the view of ascertaining whether any changes could be suggested to improve the collection. The fact that so many sewers are already built and in operation, makes any radical change at the present time expensive and practically unnecessary. In the plan now suggested by Mr. Griggs, the alignments are economical and proper.

Mr. Griggs, in his last report, suggests a number of relief storm water drains, because the older sewers were proportioned on too small a basis to serve present conditions. Among these, one of the most important is the proposed Renick Run sewer. It was already recommended by Mr. Alvord, and I see no reason for suggesting any change. The other storm water drains that are recommended likewise appear to be properly arranged.

Mr. Griggs recommends in his report a number of repairs to existing sewers, which have become defective either by settlement or wear. The recommendations were based on a special examination and assuming that the reports coincide with the facts, these repairs are certainly required in order to improve the present system, and save perhaps more expensive repairs in the near future.

In this connection, I may add that it is in the line of economy to provide a system with manholes sufficiently frequent so that both inspection and cleaning can be facilitated. The number of manholes now in existence is altogether insufficient to accomplish proper work at a low price.

In order properly to proportion the sizes of the sewers, the McMath formula is recommended, which embodies in it experience first gained in England, then in Switzerland, and finally modified by experience recorded in St. Louis. It will give satisfactory results in your case. Regarding the assumption of rainfall to be provided for in sewers, namely, a maximum flow of 2.75 inches per hour, I will say that I have made a careful examination of the rainfall records and it is my opinion that this provision satisfies the existing conditions. There may be rainfalls of greater intensity but they will be so rare that it would not be

economical to provide for them. On the other hand, I do not consider the provision extravagant, as the same figure has been successfully used in other localities of the United States, which can justly be compared with the rainfall conditions at Columbus.

Mr. Griggs has had the capacities of existing sewers computed very carefully on the basis of this formula, and the relief sewers have been designed in each case to take the amount of water which the present sewers could not receive and carry from the above mentioned depth of rainfall.

There has been considerable trouble from deposits in some of the sewers, and particularly in the large intercepting sewer which has a very slight fall. I am informed that a recent cleaning was quite expensive, and that there exist no reasons why this sewer should not gradually fill up again.

A pretty large experience in such cases, especially in Europe, indicates that these large flat sewers can be kept in a good condition, merely by a systematic inspection and a frequent cleaning by flushing with the sewage itself in the following manner: Gates are placed into the sewer at certain points, determined by local conditions. The lowest gate is closed and the water accumulates behind; it is then tripped and the water rushes out and flushes not only the stretch of sewer below the gate, but also that above the same for quite a distance. The next gate is then operated in the same manner, and so on until the upper end of the sewer is reached. A final flushing is then undertaken by opening the gates in a reverse order. This method is quite effective, if the intervals of time are not too long, and it is also economical and prevents the accumulation and eventual expensive excavation of deposited material.

The improvements suggested by Mr. Griggs for the present system have been well considered, and their cost has been estimated. I have had these items of cost gone over with a view of checking them in a general way, and believe that the estimates are sufficient for the purpose. It remains with you to state which of these repairs and extensions should be undertaken first, the order in which they shall be undertaken and the number of years over which this expenditure should be extended.

COST.

The following is the estimate of cost covering the most important constructions required. The first one is for the several pumping plants and force mains, all of which are urgent. The

second estimate includes chiefly the various relief sewers, drains, repairs, appurtenances and extensions that are also in greater part urgent.

PUMPING PLANTS.

Main pumping station and acessories	$105,000 00
Kelton avenue pumping station	20,000 00
Main street pumping station	5,000 00
Force main from Kelton avenue and Main street station	15,019 00
Total	$145,019 00

IMPROVEMENTS AND EXTENSIONS.

West Side outlets and interceptors	$12,512 00
Second avenue relief sewer and branches	69,704 00
Russell street relief sewer and branches	30,400 00
Factory street drain	4,279 00
Central relief sewer	168,421 00
Fifth street branch	40,434 00
Long street extension	4,285 00
Washington avenue relief	14,230 00
Walnut street relief and branch	23,365 00
Beck street relief and branches	27,428 00
Oak street extension	1,392 00
West Broad street storm water system	23,070 00
Glenwood avenue extension	2,155 00
Hartford avenue drain	1,821 00
Stimmel road drain	47,432 00
Sanitary sewer main, Kian Run district	73,530 00
Sanitary sewer main, west of Scioto river	197,836 00
Repairs to Peter's Run sewer and branch	16,033 00
Repairs to Spring street sewer	10,000 00
Repairs to Northwest trunk sewer	401 00
Repairs to Indianola sewer	2,281 00
Repairs to Joe alley sewer	839 00
Repairs to North Columbus sewer	1,165 00
Extension of the Intercepting sewer	3,306 00
1000 new manholes	50,000 00
500 new catch basins and lead-offs	25,000 00
20 automatic gates and manholes on Intercepting sewer	6,000 00
Grand total	$857,319 00

Mr. Griggs has prepared specifications to explain the detail construction of the proposed works. They very correctly and properly explain in general terms the manner of constructing work of this kind. When construction is actually to be under-

taken, it would be well to elaborate them in several particulars, so as to specify in greater detail some of the important matters. At such times it will, of course, be necessary to prepare also the working drawings with the same detail.

Very respectfully yours,

RUDOLPH HERING.

APPENDICES.

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Page numbers given below correspond to references in the report.

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Plate No. 5. Details of filtration beds.

Cost of sedimentation tanks.

Cost of filtration beds.

Plate No. 6. Map of Columbus, Ohio, showing existing sewers and drains and sewers proposed for immediate and future construction.

COST OF SEDIMENTATION TANKS.

Mr. Griggs' suggestion of twenty tanks, each 150x50 feet, and about 9 feet deep, containing each 500,000 gallons, is approved. These tanks will, therefore, hold about 10 million gallons of sewage, which, with the usual irregular flow, may allow for a storage of from 10 to 14 hours.

Cost of tanks per million gallons of sewage treated	$5,250 00
Cost of roofing	2,325 00
Total	$7,575 00

COST OF FILTRATION BEDS.

As a basis of estimate, it is assumed that there are 80 beds, each containing one acre of net filtering surface. The excavation is to be made of sufficient depth to provide the necessary material for all the division banks and for a dyke surrounding the entire plant and extending six feet above the high water line of 1898. The beds are to be underdrained with a common outfall into the river. They are to be artificially prepared, as shown in the plans and sections. The sand beds are constructed, as shown in the sections, with sand at a minimum depth of two feet and maximum depth of four feet, underlaid at the greater depth by gravel, in which are the underdrains. The estimate of cost includes excavation, under-drains, sand and gravel, sewage carriers and distributors. The cost per acre of net filter surface, on the basis of 80 acres, is $8940.

Should at first but 10 acres be constructed with drains and carriers arranged for future enlargement, the total cost of such 10 acres of filter beds would be $135,700.

Including settling tanks, sufficient for 20 million gallons and other items necessary for starting the purification plant, the total cost of the disposal plant with the installation of 10 acres, would be $581,566.00.

TABLE A.

Estimated Run-off, in inches, of the Scioto River at Columbus, Ohio.

Drainage Area 1580 Square Miles.

Months.	Based on Muskingum Run-off at Zanesville.								Estimated.			Based on Ohio State University Records.*	
	1888	1889	1890	1891	1892	1893	1894	1895	1896	1897	1898	1899	1900
January	1.24	1.89	3.53	2.40	0.74	0.37	1.00	1.67	0.6	2.5	2.0	3.50	1.25
February	1.12	1.42	3.73	4.56	2.40	4.70	2.19	0.12	3.8	4.5	3.2	1.03	1.61
March	1.38	0.71	4.23	2.52	1.26	2.55	1.41	1.20	3.9	2.6	2.1	3.49	2.34
April	0.80	0.88	2.00	1.58	1.38	2.22	0.75	0.59	3.6	1.6	1.15	0.86	1.16
May	0.45	0.28	3.10	0.45	2.25	4.05	0.74	0.10	3.0	1.0	0.35	0.19	0.19
June	0.29	0.47	1.64	0.91	2.30	0.78	0.42	0.17	1.2	0.8	0.25	0.32	0.20
July	0 81	0.55	0.51	0.51	0.75	0.28	0.13	0.21	0 3	0.6	0.20	0.14	0.09
August	0.67	0.22	0.49	0.35	0.60	0.16	0.11	0.11	0.2	0.4	0.15	0 26	0.25
September	0.61	0.14	2.28	0.17	0.28	0.14	0.15	0.13	0.2	0.2	0.02	0.02	0.03
October	0.77	0.14	2.01	0.26	0.20	0.46	0.10	0.08	0.4	0.3	0.02	0.02	0.02
November	2.01	0.68	1.84	0.94	0.19	0 25	0.16	0.16	0.5	1.0	0.06	0.06	0.25
December	0.84	1.48	0.91	1.03	0.24	1.54	0.36	(0.36)	0.5	1.3	0.50	0.43	0.19
Total	10.99	8.86	26.27	15.68	12.59	17.50	7.52	(4.90)	(18.2)	(16.8)	10.00	10.32	7.58

*Made for Ohio State Board of Health.

TABLE B.

Population, or thousands of persons, whose sewage could have been diluted from 1888 to 1900, by the flow of the Scioto River, Columbus, Ohio, at the rate of 4 cubic feet per second for every 1,000 persons.

Drainage Area, 1,580 Square Miles.

Months.	Based on Muskingum River Run-off at Zanesville.								Estimated.			Based on Records of Ohio State University.*	
	1888	1889	1890	1891	1892	1893	1894	1895	1896	1897	1898	1899	1900
January	**440**	**670**	**1250**	**848**	**262**	**131**	**354**	**591**	**212**	**883**	**708**	**1240**	**442**
February	**398**	**502**	**1320**	**1610**	**848**	**1660**	**725**	*42*	**1345**	**1590**	**1130**	**364**	**570**
March	**448**	**251**	**1490**	**890**	**446**	**903**	**498**	**424**	**1380**	**918**	**743**	**1230**	**827**
April	**283**	**311**	**707**	**558**	**488**	**785**	**266**	**209**	**1275**	**566**	**407**	**304**	**410**
May	**159**	*99*	**1090**	**159**	**796**	**1430**	**262**	*35*	**1060**	**354**	*124*	*67*	*67*
June	*103*	**166**	**580**	**322**	**813**	**276**	**149**	*60*	**424**	**284**	*88*	*113*	*71*
July	**287**	**195**	**180**	**180**	**266**	*99*	*46*	*74*	*106*	**213**	*71*	*50*	*32*
August	**237**	*78*	**173**	*124*	**212**	*57*	*39*	*69*	*71*	**142**	*53*	*92*	*88*
September	**216**	*99*	**806**	*60*	*99*	*50*	*53*	*46*	*71*	*71*	*7*	*7*	*11*
October	**273**	*49*	**707**	*92*	*71*	**163**	*35*	*28*	**142**	*106*	*7*	*7*	*7*
November	**707**	**241**	**650**	**333**	*67*	*88*	*57*	*57*	**177**	**354**	*21*	*21*	*88*
December	**297**	**524**	**322**	**364**	*85*	**545**	**127**	**127**	**177**	**460**	**177**	**152**	*67*
Average,	323	261	775	462	371	516	222	141	537	487	295	304	223

*Made for Ohio State Board of Health.

The black figures indicate the months when the sewage from the present population could have been discharged into the river without offense.

TABLE C.

Rate of filtration, in thousand gallons per acre per day, necessary to dispose of the sewage of 125,000 persons on 80 acres of Artificial sand beds, after deducting the sewage diluted by the flow of the Scioto River.

(See Table C.) (160 gallons per person.)

Month	Based on Muskingum River Run-off at Zanesville								Estimated			Based on Records of Ohio State University*	
	1888	1889	1890	1891	1892	1893	1894	1895	1896	1897	1898	1899	1900
January	0	0	0	0	0	0	0	0	0	0	0	0	0
February	0	0	0	0	0	0	0	166	0	0	0	0	0
March	0	0	0	0	0	0	0	0	0	0	0	0	0
April	0	0	0	0	0	0	0	0	0	0	0	0	0
May	0	52	0	0	0	0	0	180	0	0	4	116	116
June	44	0	0	0	0	0	0	130	0	0	74	24	108
July	0	0	0	0	0	52	158	102	38	0	108	150	186
August	0	94	0	2	0	136	172	172	108	0	144	66	74
September	0	152	0	130	52	150	144	158	108	108	236	236	228
October	0	152	0	66	108	0	180	194	0	38	236	236	236
November	0	0	0	0	116	74	136	136	0	0	208	208	74
December	0	0	0	0	80	0	0	0	0	0	0	0	116
Average	44	113	0	66	89	103	158	155	84	73	144	148	142
Annual Average	4	38	0	17	30	34	66	103	21	12	84	87	95

*Made for the Ohio State Board of Health.

TABLE D.

Table showing the precipitation and run-off, in inches, on the watershed of the Muskingum River above Zanesville, from December 1, 1887, to November 30, 1895.

Month	1888		1889		1890		1891	
	Rainfall	Run-off	Rainfall	Run-off	Rainfall	Run-off	Rainfall	Run-off
December	1.94	.180	1.50	.835	3.01	1.476	2.45	.912
January	3 96	1 241	3.63	1.893	4.52	3.532	2.52	2.402
February	1.91	1.119	1.55	1.421	5.84	3.725	4.43	4.564
March	4.05	1.377	1.71	.707	4.38	4.229	3.19	2.523
April	1.75	.796	2.23	.881	3.41	1.998	1.74	1.584
May	3.55	.451	2.90	.277	6.61	3.095	2.39	.446
June	2.66	.289	4.79	.467	5.27	1 635	7.56	.907
July	5.81	.811	5.35	.547	3.06	.505	3.92	.508
August	5.84	.669	1.98	.224	5.35	.485	2.08	.345
September	3.28	.609	4.17	.137	6.86	2.279	1.08	.172
October	3.25	.768	2.35	.136	6.20	2.014	1.25	.258
November	4.61	2.006	3.72	.681	2.46	1.835	4.75	.944
Total	42.61	10.316	*36.05	8.206	*58.97	26.808	*37.97	15.565

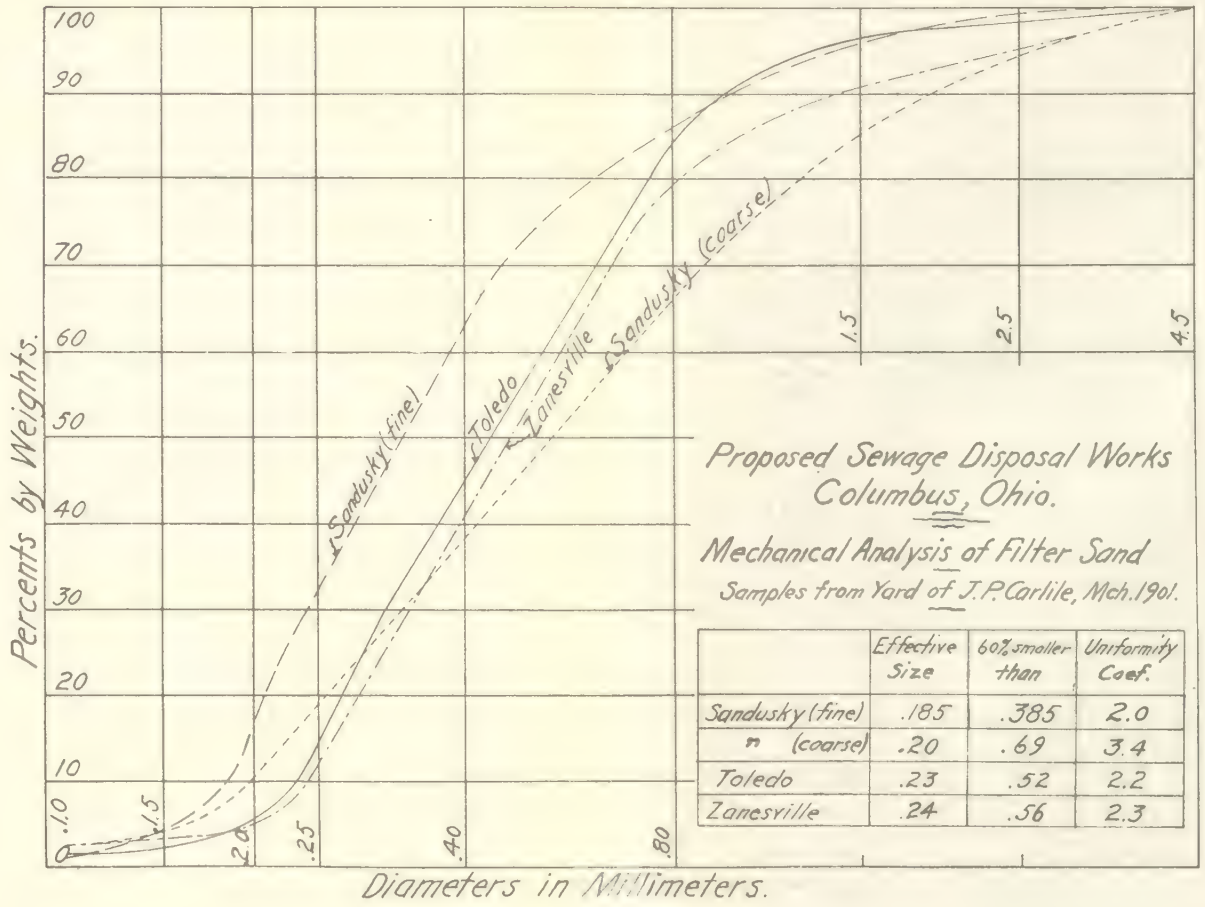
*These columns in the original document evidently contain typographical errors.

TABLE D—Continued.

Month	1892		1893		1894		1895	
	Rainfall	Run-off	Rainfall	Run-off	Rainfall	Run-off	Rainfall	Run-off
December	2.62	1.034	1.62	.236	2.59	1.538	3.01	.359
January	2.40	.737	3.01	.365	2.11	1.004	3.99	1.667
February	2.76	2.401	6.38	4.698	2.95	2.185	.89	.118
March	3.10	1.257	2.31	2.549	2.20	1 412	1.87	1.202
April	2.24	1.383	5.94	2.216	2 45	.751	1.76	.587
May	7.27	2.254	5.78	4.052	4.63	.741	1.52	.095
June	7.05	2.301	3.08	.778	2.12	.416	2.87	.166
July	5.44	.748	2.92	.276	1.77	.133	2.52	.211
August	4.05	.604	2.31	.163	.67	.109	3.75	.110
September	2.33	.282	1.56	.142	4.12	.151	2.39	.131
October	.80	.196	5.51	.464	2.19	.098	1.38	.084
November	1.68	.188	1.94	.247	2.71	.159	3.89	.163
Total	41.74	*13.386	42.36	16.186	30.51	8.697	29.84	4.893

*These columns in the original document evidently contain typographical errors.

PLATE No. I.



Proposed Sewage Disposal Works
Columbus, Ohio.

Mechanical Analysis of Filter Sand

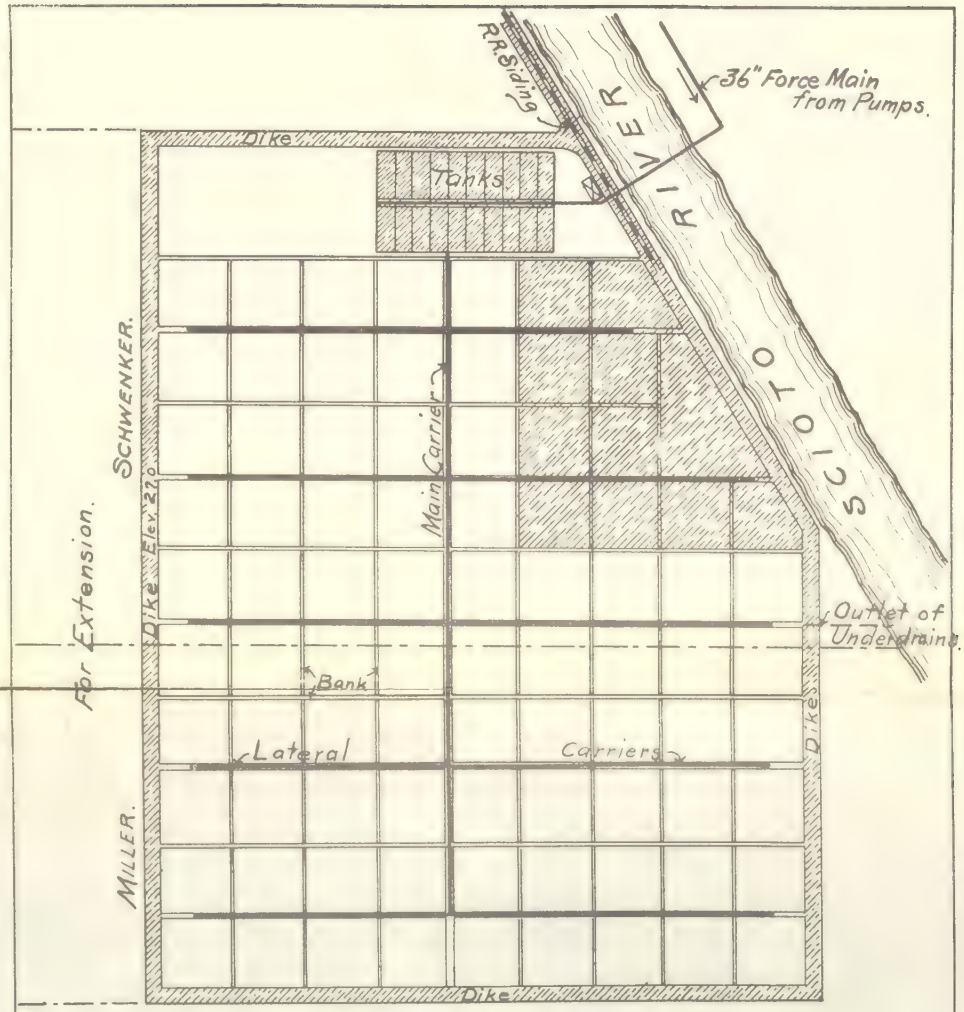
Samples from Yard of J. P. Carlile, Mch. 1901.

	Effective Size	60% smaller than	Uniformity Coef.
Sandusky (fine)	.185	.385	2.0
" (coarse)	.20	.69	3.4
Toledo	.23	.52	2.2
Zanesville	.24	.56	2.3

PLATE No. 2.

OLENTANGY RIVER
N
ST.
SCIOTO RIVER
West Side District
BROAD
ST.
Pumping Stations
ALUM CREEK
HIGH
Pumping Station
Main Run District
SCIOTO RIVER
Disposal Area
Canal
Note
Hached areas are sewered on the separate system, all other areas are sewered on the combined system.
Proposed Sewage Disposal Works
Columbus, Ohio.
General Plan Showing Location of Main Sewers and Disposal Plant.
Scale ft. to an inch.

PLATE No. 3.



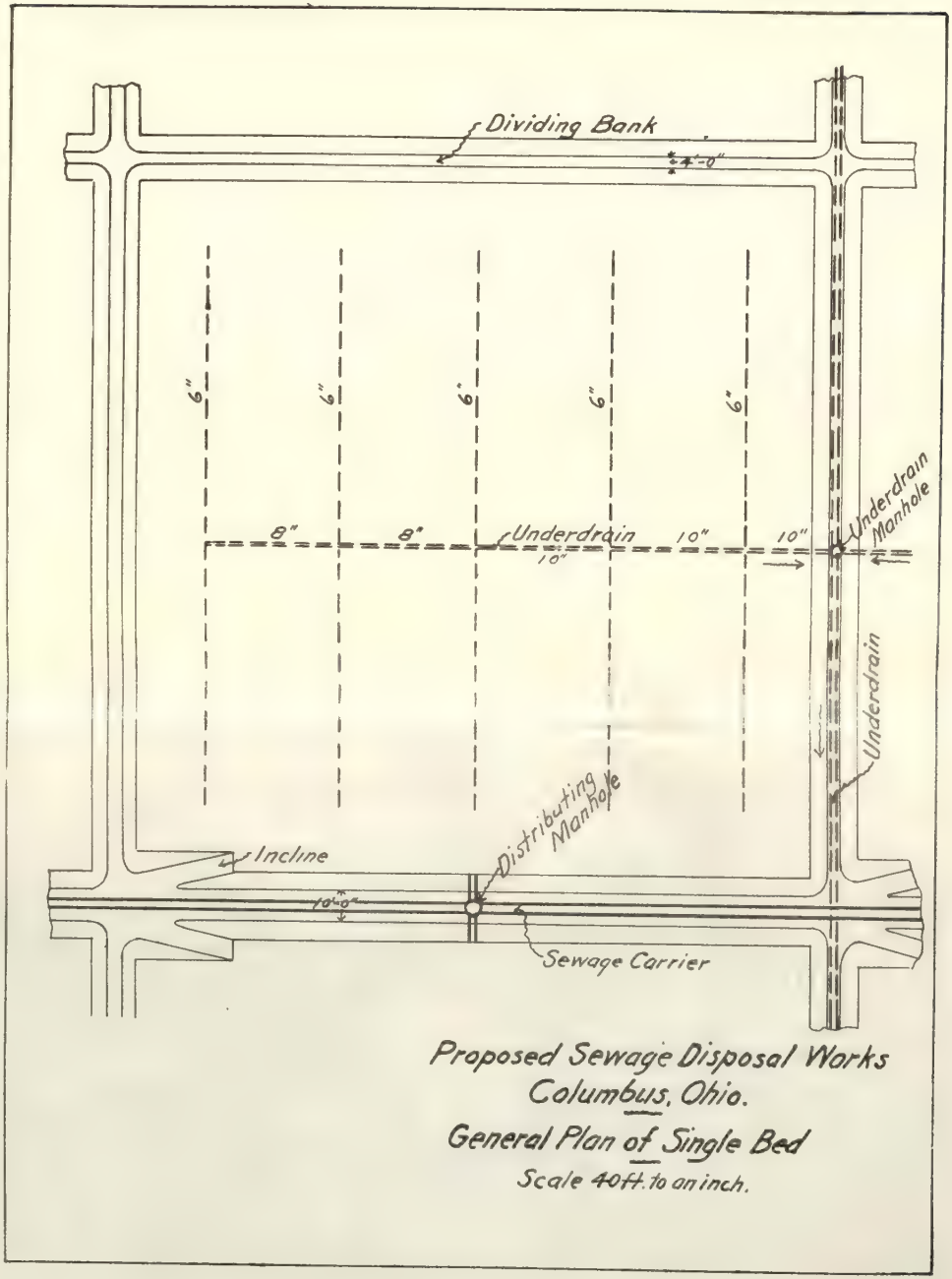
Proposed Sewage Disposal Works
Columbus, Ohio.

Plan of Tanks and Beds.

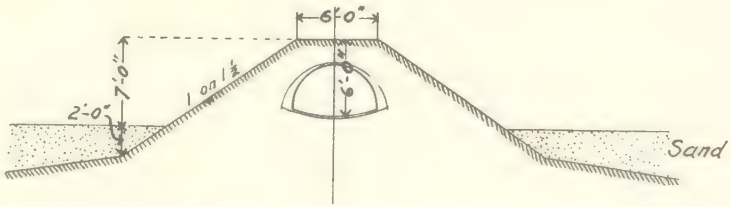
Scale 400 ft. to an inch.

Note
Hached areas recommended
for immediate construction.

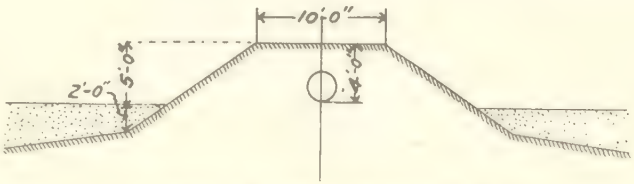
PLATE No. 4.



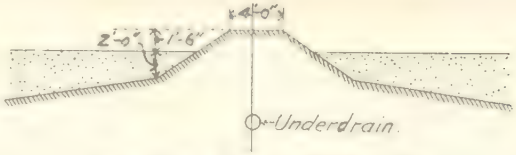
Proposed Sewage Disposal Works
Columbus, Ohio.
General Plan of Single Bed
Scale 40ft. to an inch.



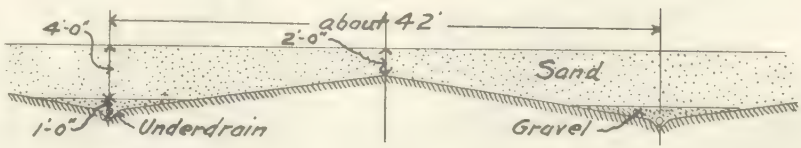
Section of Main Carrier Bank



Section of Lateral Carrier Bank



Section of Ordinary Bank



Section of Bed across Underdrain.

Proposed Sewage Disposal Works
Columbus, Ohio.
Details of Filtration Beds.
Scale 10 ft. to an inch.

MAP OF COLUMBUS, O.

Scale 1200 Ft. per Inch

NOTE—Black lines represent the larger existing sewers.

Full red lines represent proposed storm water drains, and combined sewers for immediate construction.

Broken red lines represent proposed storm water drains and combined sewers for future construction.

Full yellow lines represent proposed sanitary sewers for immediate construction.

Broken yellow lines represent proposed sanitary sewers for future construction.

The tinted portion of the map shows area of the city proposed to be sewered on the separate system.

The Ohio State University
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A report to the President of Sewer Commi
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